EFFECT OF SOME PHENOLIC COMPOUNDS ON SPORE GERMINATION AND GERM-TUBE LENGTH OF *ASPERGILLUS FUMIGATUS* AND *FUSARIUM OXYSPORUM* F. SP. *LYCOPERSICI*

by Ismail Mohamed Kamel ISMAIL, Abdel-Aziz Mahmoud SALAMA, Mohamed Ibrahim Ahmed ALI and Salama Abu-Elyazeed OUF*

ABSTRACT. — The effects of 12 different phenolic compounds on the percentage germination and germ-tube lengths of spores of *Aspergillus fumigatus* Fresenius and *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) Snyder & Hansen were studied. The results indicate that the compounds vary in their inhibitory action on the spores of these two fungi depending on dosage, the organism under test and the chemical structure of the compounds. Gallic acid, resorcinol, *m*-digallic acid and hydroquinone insignificantly affected the percentage spore germination of both fungi, even at high concentrations. The remaining compounds, on the other hand, revealed different inhibitory levels which could be arranged from the least inhibitory compound to the most in the order pyrogallol, 2,4-dinitrophenol, phenol, salicylic acid, *p*-cresol, *m*-cresol, *o*-cresol and *o*-nitrophenol. The effects of the 12 phenolic compounds on the germ-tube lengths of the two fungi were generally similar to those of spore germination.

RÉSUMÉ. — Étude de l'effet de 12 composés phénoliques sur la germination et la croissance des tubes germinatifs d'*Aspergillus fumigatus* Fresenius et de *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) Snyder & Hansen. Les résultats indiquent que ces composés ont des effets inhibiteurs variables sur les spores des deux champignons, qui dépendent des doses appliquées, de l'organisme testé et de la structure chimique du composé. L'acide gallique le résorcinol, l'acide tannique et l'hydroquinone, ont un effet insignifiant sur le pourcentage de germination des spores des deux champignons, même à des concentrations élevées. Par contre, les autres composés sont inhibiteurs à différents niveaux, et peuvent être classés du moins inhibiteur au plus inhibiteur comme suit : pyrogallol, 2,4-dinitrophenol, phenol, acide salicylique, *p*-cresol, *m*-cresol, *o*-cresol, et *o*-nitrophenol. Généralement, l'effet des 12 composés phénoliques sur la croissance des tubes germinatifs est semblable à celui observé sur la germination des spores.

KEY WORDS : Phenolic compounds, spore germination, germ-tube length, *Aspergillus fumigatus*, *Fusarium oxysporum* f. sp. *lycopersici*, gallic acid, resorcinol, *m*-digallic acid, hydroquinone, pyrogallol, phenol, 2,4-dinitrophenol, salicylic acid, *o*-nitrophenol, *o*-cresol, *m*-cresol, *p*-cresol.

* Department of Botany, Faculty of Science, University of Cairo, Egypt.

INTRODUCTION

Phenolic compounds are known to be toxic to a great number of microorganisms. Biocides containing phenolic group(s) in their structure have been used in pest control such as dinitrocresol (VERONA, 1950) and fluometuron (cotoran or [3-(3-trifluoromethyl phenyl)-1,1 dimethyl urea]) (TWEEDY & LEOPPKY, 1968; NAGUIB, 1969). SHORTLE & al. (1971) indicated that ortho-dihydroxyphenolic compounds, such as catechol, are much more inhibitory to *Phialophora melinii* than are meta- or para-dihydroxyphenols, such as resorcinol and hydroquinone, respectively. Poor growth of *Fomes connatus (Oxyporus populinus)* on gallic acid medium has been reported as characteristic of the fungus (NOBLES, 1948).

Spore germination of *Diplodia gossypina* was reduced greatly by catechol, catechin, coumarin, as well as tannic, chlorogenic, D(-) quinic, gallic, or caffeic acids and to a lesser extent by resorcinol and pyrogallol (WANG & PINCKARD, 1973).

PATIL & al. (1964) indicated that the quinone form of chlorogenic acid, even at low concentrations, was toxic to spore germination of *Verticillium albo-atrum* and that polymerized products had little toxicity. ISMAIL & MICHALIKOVA (1977) studied the effect of some phenolic compounds on spore germination of *Helminthosporium sativum* and showed that 2,4-dinitrophenol, 8-hydroxyquinoline and pyrocatechin were significantly stimulatory to spore germination at low concentrations, while they were significantly inhibitory at higher concentrations. They also found that salicylic acid, gallic acid and tannin activated spore germination of *H. sativum* with highly significant differences. ORELLANA & THOMAS (1965) reported that gallic acid may promote germination, growth and sporulation of *Botryotinia ricini*. VIDHYASEKARAN (1974) showed that oxidized phenolics markedly inhibited spore germination, mycelial growth and the activity of pectic and cellulolytic enzymes of *Helminthosporium* sp.

In the literature, there exist a number of studies dealing with phenolic compounds as enzyme inactivators or inhibitors (PATIL & DIMOND, 1967; RAVISE & KIRKIACHARIAN, 1976).

Phenolic compounds are widely distributed in higher plants and fungi. Mostly, they represent polymerized terminal products of secondary metabolism. The variety of structure they offer provides a basis for a degree of specificity as antimicrobial agents (BILGRAMI & DUBE, 1976). Therefore, phenols or tannins have been implicated as possible cause of disease resistance in plants (WALKER & STAHMANN, 1955). Phenolic compounds accumulate rapidly during host-parasite interactions (CRUICKSHANK, 1980) and can mediate disease suppression through inactivation of fungal enzymes or strengthening of plant structural components (LEATHAM & al., 1980). LINK (1933) reported that coloured onion varieties resistant to *Colletotrichum circinans* (causal organism of smudge disease) contained more catechol and protocatechuic acid in their bulb scales than did less resistant varieties. Later, WALKER & LINK (1935) found that

these two compounds were toxic to the organism *in vitro* and revealed, when testing other phenolic compounds on *C. circinans* and 3 other fungi, that toxicity of such compounds was dependent on the molecular structure of the phenol.

In this paper we report the effects of twelve phenolic compounds on *Aspergillus fumigatus* Fresenius and *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) Snyder & Hansen. This is a preliminary study to determine the significance of use of plant residues rich in phenolic contents instead of chemical phenolic compounds as a method for controlling plant diseases through soil amendment with these plant residues. This is our future goal.

MATERIALS AND METHODS

Organisms

Two fungi were selected for the study : *Aspergillus fumigatus* Fresenius and *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) Snyder & Hansen. The former organism was isolated from Egyptian soil and chosen due to the high percentage germination of its conidia, its sensitivity to fungicides and saprophytic nature. These characters were valuable in using this organism for comparison with the pathogenic fungi. The latter organism, an important plant pathogen causing tomato wilt in Egypt, was isolated from infected tomato plants in Egypt.

Phenolic compounds

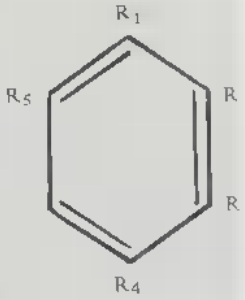
Twelve phenolic compounds were used, each in seven concentrations namely 0, 10, 50, 100, 250, 500, 1000 ppm.

For each treatment of each phenolic compound, 7 erlenmeyer flasks (250 ml) each containing 90 ml of previously prepared Czapek's agar medium (THOM & RAPER, 1945) were melted and cooled to about 50°C. Each of 6 flasks received 10 ml of previously prepared stock solutions of the phenolic compounds. The flasks were then shaken to assure uniform distribution yielding the above mentioned concentrations for each phenolic compound. To the 7th flask 10 ml of sterile distilled water were added to serve as a control. Sufficient amount of the mixture in each of the 7 flasks was then poured into each of 4 sterile Petri plates (90 mm diameter) to form upon solidification a thin layer at the bottom.

Two plates were surface inoculated with 1 ml spore suspension of *Fusarium oxysporum* f. sp. *lycopersici* and the remaining duplicate were inoculated with *Aspergillus fumigatus*. All plates were then incubated at 27°C.

The following phenolic compounds were chosen for the present study :

	R_1	R_2	R_3	R_4	R_5
1 phenol	OH	H	H	H	H
2 resorcinol	OH	H	OH	H	H
3 hydroquinone	OH	H	H	OH	H
4 pyrogallol	OH	OH	OH	H	H
5 *o*-cresol	OH	CH_3	H	H	H
6 *m*-cresol	OH	H	CH_3	H	H
7 *p*-cresol	OH	H	H	CH_3	H
8 *o*-nitrophenol	OH	NO_2	H	H	H
9 2,4-dinitrophenol	OH	NO_2	H	NO_2	H
10 salicylic acid	OH	COOH	H	H	H
11 gallic acid	OH	OH	H	COOH	OH
12 *m*-digallic acid	OH	OH	H	$C_8H_5O_6$	OH



Preparation of spore suspension

Both *Fusarium* and *Aspergillus* spp. were separately inoculated into fresh plates of Czapek's agar medium (THOM & RAPER, 1945) and the plates were incubated at 25°C for 7 days. The spores were harvested from margins of the colonies using a sterile needle and transferred into test tubes containing 5 ml of sterile distilled water. The tubes were manually shaken for 5 min. to allow for even dispersal of spores.

Estimation of percentage germination

Several preliminary trials were made to estimate the time interval (in hours) needed for the control of each species to give about 50 % germination. This estimated time interval was carried out in separate control plates and was taken as a limit at which the variously treated plates were examined. This estimated time interval for controls was found to be 13.5 hrs for *Aspergillus fumigatus* and 4.5 hrs for *Fusarium oxysporum* f. sp. *lycopersici*.

By the end of the needed incubation period 2 agar blocks from each plate were removed on labelled slides and transferred to a desiccator with a vapour of formalin to fix and kill the spores. Four microscopic fields (magnification power x 100) per block were then examined at random for their content of percentage germinated spores and lengths of germ-tubes in microns (i. e. 16 readings for each treatment).

RESULTS

Fusarium oxysporum f. sp. *lycopersici*

Table 1 shows the average values of percentage spore germination at different concentrations of each of the studied phenolic compounds. The increase in

TABLE I

Effect of different concentrations of some phenolic compounds on percentage spore germination (% germ., control = 51.66 %) and length of germ tube μm (g. t. leng., control = 18.64 μm) of *F. oxysporum* f. sp. *lycopersici* after 4.5 hrs on Czapek's medium at 27°C.

TABLEAU I

Effet de différentes concentrations de quelques composés phénoliques sur la germination des spores (% germ., témoin = 51,66 %) et la croissance des tubes germinatifs μm (g.t. leng., témoin = 18,64 μm) de *Fusarium oxysporum* f. sp. *lycopersici* après 4,5 h sur milieu de Czapek à 27°C.

Phenol's number	10 ppm		50 ppm		100 ppm		250 ppm		500 ppm		1000 ppm	
	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.
1	52.66	18.57	50.25	17.65	44.25	15.37	29.33	14.15	6.33	9.99	0.00	0.00
2	53.33	19.17	52.25	18.97	49.66	18.51	49.50	18.48	49.00	18.48	48.25	18.31
3	53.33	18.10	52.66	18.77	51.33	18.74	50.00	18.57	49.33	18.57	49.00	18.48
4	52.33	18.77	50.66	18.74	43.33	16.59	35.50	14.05	22.25	10.36	5.25	9.63
5	47.00	17.88	43.33	13.56	23.33	10.72	0.00	0.00	0.00	0.00	0.00	0.00
6	47.50	17.95	44.00	14.05	26.33	11.88	0.00	0.00	0.00	0.00	0.00	0.00
7	49.25	18.15	45.33	16.23	29.33	12.87	15.25	9.53	0.00	0.00	0.00	0.00
8	43.33	16.20	18.33	10.56	5.50	7.22	0.00	0.00	0.00	0.00	0.00	0.00
9	47.33	17.65	46.66	17.19	40.66	14.68	36.50	13.89	16.33	10.62	0.00	0.00
10	50.66	18.44	49.25	17.25	43.25	16.56	37.33	14.25	2.66	6.79	0.00	0.00
11	51.00	16.43	48.25	14.28	48.25	13.20	48.00	11.22	47.66	10.56	47.50	9.93
12	54.33	19.04	52.66	18.87	51.66	18.81	51.33	18.21	51.33	17.85	51.00	17.58

Least significant difference (L.S.D.)	Between treatments		Within treatment	
	% germ	g. t. leng.	% germ	g. t. leng.
at p = 0.05	10.06	3.29	7.68	2.52
at p = 0.01	14.21	4.65	10.85	3.55

TABLE 2

Effect of different concentrations of some phenolic compounds on percentage spore germination (% germ., control = 48.75 %) and length of germ tube μm (g. t. leng., control = 25.27 μm) of *A. fumigatus* after 13.5 hrs on Czapek's medium at 27°C.

TABLEAU 2

Effet de différentes concentrations de quelques composés phénoliques sur la germination des spores (% germ., témoin = 48.75 %) et la croissance des tubes germinatifs μm (g.t. leng., témoin = 25,27 μm) d'*Aspergillus fumigatus* après 13,5 h sur milieu de Czapek à 27°C.

Phenol's number	10 ppm		50 ppm		100 ppm		250 ppm		500 ppm		1000 ppm	
	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.	% germ	g. t. leng.
1	45.00	22.53	26.66	14.38	20.25	13.49	0.00	0.00	0.00	0.00	0.00	0.00
2	52.50	25.47	51.66	25.27	44.66	20.49	42.50	19.49	41.33	19.30	41.33	18.90
3	56.50	26.43	52.50	25.41	48.33	24.51	45.50	22.83	43.66	21.84	43.00	20.49
4	48.25	23.79	47.33	23.16	43.50	16.23	38.50	13.62	6.33	8.94	0.00	0.00
5	38.00	19.53	26.33	13.86	19.25	12.93	0.00	0.00	0.00	0.00	0.00	0.00
6	38.66	19.76	27.25	14.22	19.75	13.13	0.00	0.00	0.00	0.00	0.00	0.00
7	40.33	21.28	30.75	14.52	23.33	13.92	0.00	0.00	0.00	0.00	0.00	0.00
8	33.75	15.84	1.66	7.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	43.66	21.32	41.25	18.94	40.50	14.81	28.50	13.79	0.00	0.00	0.00	0.00
10	47.50	23.82	45.33	22.47	30.66	15.24	24.00	13.22	0.00	0.00	0.00	0.00
11	57.33	26.10	50.33	25.50	48.50	25.08	48.00	24.81	45.00	24.75	42.33	24.15
12	53.33	26.23	54.33	25.80	50.25	25.44	50.00	25.34	50.00	25.08	49.33	24.53

Least significant difference (L.S.D.)	Between treatments		Within treatment	
	% germ	g. t. leng.	% germ	g. t. leng.
at p = 0.05	9.29	4.41	7.10	3.36
at p = 0.01	13.12	6.22	10.02	4.75

concentration of certain compounds resulted in a decrease percentage of spore germination, while that of other compounds was of little or no influence. Therefore, the phenolic compounds included in this study were grouped into two categories based on their effect on percentage spore germination. These were (a) gallic acid, resorcinol, tannic acid (*m*-digallic acid) and hydroquinone which revealed no significant effects as compared to their respective control values; (b) pyrogallol, 2,4-dinitrophenol, phenol, salicylic acid, *p*-cresol, *m*-cresol, *o*cresol, *o*-nitrophenol. The lethal dosages of such compounds were 1000 ppm for the first 4 compounds except for that of pyrogallol which was more than 1000 ppm, 500 ppm for *p*-cresol and 250 ppm for the last 3 compounds.

It appears that although most of the studied compounds were lethal to macroconidia of *F. oxysporum* f. sp. *lycopersici* at relatively high concentrations (> 50 ppm), none of them, except *o*-nitrophenol, revealed any significant toxicity at lower concentrations (10 & 50 ppm).

The effects of different concentrations of some phenolic compounds studied on the lengths of germ tubes were generally similar to their effects on the percentage spore germination.

At the highest concentration (1000 ppm) almost all compounds in groups (b) were lethal to the macroconidia of this fungus.

Aspergillus fumigatus

All compounds except gallic acid, *m*-digallic acid and hydroquinone variably affected spore germination especially at high concentration (Table 2). Although some of these compounds were lethal even at relatively low concentrations, others were inhibitory only at higher dosages. Resorcinol, gallic acid and hydroquinone were only slightly toxic at the highest concentration (1000 ppm); the latter two compounds revealed statistically significant activation in spore germination of *A. fumigatus* when present at the lowest concentration used (10 ppm). The remaining phenolic compounds possessing more inhibitory effect on spore germination can be arranged according to their effect from the least inhibitory compound to the most in the order pyrogallol, 2,4-dinitrophenol, salicylic acid, *p*-cresol, *m*-cresol, *o*-cresol, *o*-nitrophenol. Complete inhibition of spore germination was achieved at 100 ppm of *o*-nitrophenol, at 250 ppm of cresols and phenol, and at 500 ppm of salicylic acid and 2,4-dinitrophenol. Pyrogallol, however, did not completely inhibit but greatly retarded spore germination at 500 ppm concentration.

The results of the effects of the various phenolic compounds on germ tube lengths of *A. fumigatus* revealed that *m*-digallic acid and gallic acid displayed no significant effects at any of the concentrations used. Resorcinol and hydroquinone slightly retarded germ tube elongations at the highest concentrations (500 & 1000 ppm). The lengths of germ tubes were greatly reduced by *o*-nitrophenol and to a lesser extent by the cresols and phenol. Pyregallol showed much less effects on germ tube length than cresols or phenol.

DISCUSSION

Our results indicate clear toxicity variabilities between tested phenolic compounds depending on the dosage, organism under test, period of incubation or contact as well as the chemical structure of the compound. In case of *Aspergillus fumigatus* and *Fusarium oxysporum* f. sp. *lycopersici*, gallic acid, resorcinol, *m*-digallic acid and hydroquinone insignificantly affected the percentage spore germination of both fungi even at high concentrations. The remaining compounds, on the other hand, revealed different inhibitory levels which could be arranged according to their effect from the least inhibitory to the most in the order : pyrogallol, 2,4-dinitrophenol, phenol, salicylic acid, *p*-cresol, *m*-cresol, *o*-cresol, *o*-nitrophenol.

The effects of the 12 tested phenolic compounds on the germ tube lengths of the same two fungi were generally harmonious with those of spore germination.

The toxic effect of phenolic compounds on spore germination *in vitro* was studied by many authors. BILGRAMI & VERMA (1978) reported that a variety of plant products, including phenols, mustard oils, etc. have inhibitory effects on spore germination. SILVIA & SINCLAIR (1983 a-b) stated that a diffusible substance produced by *Laccaria laccata* inhibited mycelial growth and delayed spore germination of *Fusarium oxysporum*. On the other hand, CHEO (1982) stated that while rhizomorph development as well as mycelial growth of the fungus *Armillaria mellea* were strongly stimulated by addition of tannic acid (0.3 to 1 %) to the basal medium, growth of many other fungi was inhibited.

Considering spore germination as the first step or phase of growth, the present work can thus be correlated with published reports dealing with the effects of phenolic compounds on growth of fungi. WALKER & LINK (1935) showed that in the phenol and phenolic acid series, toxicity increased with the molecular weight of the compounds in which the hydroxyl groups are arranged in ortho-position to one another on the benzene nucleus. The reverse being true in those in which the hydroxyl groups stand in meta-position to one another. Hence, phenol, catechol and salicylic acid retarded the growth of all fungi tested. These findings are in agreement with our results where phenol and salicylic acid displayed great inhibitory effects while resorcinol (-OH in *m*-position) resulted in less or no effect. Likewise, SHORTLE & al. (1971) indicated that ortho-dihydroxyphenolic compounds such as catechol, were much more inhibitory to *Phialophora melinii* than were meta- or para-hydroxyphenols, such as resorcinol and hydroquinone respectively. Moreover, LE TOURNEAU & al. (1957) reported that the meta isomer of phenol (resorcinol) had no effect on *V. albo-atrum*, while the para isomer (hydroquinone) reduced growth considerably though not as effective as catechol. On the contrary, we have found that for both fungi hydroquinone (-OH in *p*-position) and resorcinol (-OH in *m*-position) caused negligible effects.

Concerning pyrogallol (1,2,3-trihydroxybenzene), LE TOURNEAU & al. (1957) found that it was the most inhibitory compound to V. *albo-atrum* at

1×10^{-4} M. The toxicity of this compound to other fungi had also been reported by others (WALKER & LINK, 1935; GREATHOUSE & RIGLER, 1940). In the present investigation, however, pyrogallol was moderate toxicity to the two fungi studied.

The present study also showed that *o*-cresol was more inhibitory to *A. fumigatus* and *F. oxysporum f.* sp. *lycopersici* than *m*-cresol and *p*-cresol, and the three cresols were more toxic than phenol. These data lead to the suggestion that an introduction of a methyl group ($-CH_3$) in ortho-position to the phenol molecule produces a more inhibitory compound than otherwise.

The results also provide an evidence that a nitro group in ortho-position of the phenol molecule (*o*-nitrophenol) produces a more toxic compound than phenol itself. However, the introduction of another nitro group but in the para-position (2,4-dinitrophenol) does not lead to more toxicity than *o*-nitrophenol.

REFERENCES

BILGRAMI K.S. and DUBE H.C., 1976 – *A text book of modern plant pathology*. New Delhi, Vikas Publishing House PVT LTD, 144 p.

BILGRAMI K.S. and VERMA R.N., 1978 – *Physiology of fungi*. New Delhi, Vikas Publishing House PVT LDT, 369 p.

CHEO P.C., 1982 – Effects of tannic acid on rhizomorph production by *Armillaria mellea*. *Phytopathology* 72 : 676-679.

CRUICKSHANK I.A.M., 1980 Defenses triggered by the invader : Chemical defenses. *In* : HORSFALL J.G. & COWLING E.B., *Plant disease, an advanced treatise*. Vol. V, *How plants defend themselves*. New York, Academic Press : 247-267.

GREATHOUSE G.A. and RIGLER N.E., 1940 – The chemistry of resistance of plant to *Phymatotrichum* root rot. IV. Toxicity of phenolic and related compounds. *Amer. J. Bot.* 27 : 99-107.

ISMAIL I.M.K. and MICHALIKOVA A., 1977 – Effect of phenolic and other compounds on the germination of spores of *Helminthosporium sativum* Pam., King et Bakke *in vitro*. *Polnohospodarstvo (Nitra)* 23 : 18-33.

LEATHAM G.F., KING V. and STAHMANN M.A., 1980 – *In vitro* protein polymerization by quinones or free radicals generated by plant or fungal oxidative enzymes. *Phytopathology* 70 : 1134-1140.

LE TOURNEAU D., McLEAN J.G. and GUTHRIE J.W., 1957 - Effect of some phenols and quinones on growth *in vitro* of *Verticillium albo-atrum*. *Phytopathology* 47 : 602-606.

LINK K.P., 1933 – The isolation of catechol from pigmented onion scales and its significance in relation to disease resistance in onions. *J. Biol. Chem.* 100 : 379-383.

NAGUIB M.I., 1969 – Effect of sevin on the metabolism of *Rhizoctonia solani*. *U.A.R. J. Bot.* 11 : 7-18.

NOBLES M.K., 1948 – Identification of cultures of wood-rotting fungi. Studies in forest pathology. *Canad. J. Res., Sect. C. Bot. Sci.* 26 : 281-431.

ORELLANA R.G. and THOMAS C.A., 1965 – Effect of gallic acid on germination, growth and sporulation of *Botryotinia ricini*. *Phytopathology* 55 : 468-470.

PATIL S.S., POWELSON R.L. and YOUNG R.A., 1964 – Relation of chlorogenic acid and free phenols in potato roots to infection by *Verticillium albo-atrum*. *Phytopathology* 54 : 531-535.

PATIL S.S. and DIMOND A.E., 1967 – Inhibition of *Verticillium* polygalacturonase by oxidation products of polyphenols. *Phytopathology* 57 : 492-496.

RAVISE A. and KIRKIACHARIAN B.S., 1976 – Influence of structure of phenolic compounds on the inhibition of *Phytophthora parasitica*. II. Coumarins. *Phytopathology* 66 : 314-326.

SHORTLE W.C., TATTAR T.A. and RICH A.E., 1971 – Effects of some phenolic compounds on the growth of *Phialophora melinii* and *Fomes connatus*. Phytopathology 61 : 552-555.

SILVIA D.M. and SINCLAIR W.A., 1983a – Suppressive influence of *Laccaria laccata* on *Fusarium oxysporum* and on Douglass-fir seedlings. *Phytopathology* 73 : 384-389.

SILVIA D.M. and SINCLAIR W.A., 1983b – Phenolic compounds and resistance to fungal pathogens induced in primary roots of Douglas-fir seedlings by the ectomycorrhizal fungus *Laccaria laccata*. *Phytopathology* 73 : 390-397.

THOM C. and RAPER K.B., 1945 – *A manual of the Aspergilli*. Baltimore, Williams and Wilkins Co., 373 p.

TWEEDY B.G. and LEOPPKY C., 1968 – The use of C^{14}-labelled glucose, glucuronate and acetate to study the effect of atrazine, simazine and fluometuron on glucose catabolism in selected plant pathogenic fungi. *Phytopathology* 58 : 1522.

VERONA D., 1950 – Effect of some selective weed-killers in microorganisms with special reference to those of the soil. *Soils & Fertilizers* 13 : 53-237.

VIDHYASEKARAN P., 1974 – Pathophysiology of the resistance of finger-millet to helminthosporiose. *Indian J. Agric. Sci.* 44 : 434-436.

WALKER J.C. and LINK K.P., 1935 – Toxicity of phenolic compounds to certain onion bulb parasites. *Bot. Gaz. (Crawfordsville)* 96 : 468-484.

WALKER J.C. and STAHMANN M.A., 1955 – Chemical nature of disease resistance in plants. *Annual Rev. Pl. Physiol.* 6 : 351-366.

WANG S.C. and PINCKARD J.A., 1973 – Spore germination of *Diplodia gossypina* in the presence of carbohydrates and phenolic compounds in relation to boll rot of cotton. *Phytopathology* 63 : 1181-1185.